Activity At A Glance

Purpose
To understand life's key requirements and identify places in the solar system that might fulfill those requirements

Task for Students to Accomplish in This Activity
Using the information in the Planetary Information Sheets, identify the strongest candidates for life out of the nine planets and 61 moons in our solar system. This activity can be done equally well on-line or from printed versions of the pdfs.

Grade Level: 5-12

Time
- Day 1: Introduction, preassessment, compare habitability on Earth and Mercury
- Day 2: Identify factors essential for life, compare habitability on Venus and Jupiter
- Day 3: Students examine the remaining Planetary Information Sheets
- Day 4: Students identify the strongest candidates for life and present their choice(s)

Overview
Students begin by revealing their ideas of what alien life looks like. Next, they examine Information Sheets detailing each planet and the seven largest moons to become familiar with the actual conditions in our solar system. They rank the planets and moons as likely, possible, or unlikely places for life. After discussing the connections between planetary features and the possibilities for life, students refine their list. Finally, students synthesize their understanding by producing a poster report and debating contrasting positions.

Key Concepts
- Our solar system has nine planets and 61 moons.
- Except for Earth, life is not readily apparent on any planet or moon in our solar system.
- Life has basic requirements such as food, water, and a suitable temperature and habitat.
- Planetary features provide clues to specific geologic processes or planetary conditions. As a result, these features can be used to identify places that may be conducive to life.
- Looking for conditions conducive for life is easier than looking for actual organisms.
- Several of the planets and moons have or had conditions that might be conducive to life.
- Except for Earth, each planet/moon currently has major limitations for life, as we know it.
- If organisms exist in our solar system beyond Earth, they are probably very small.
- We are currently exploring our solar system with a series of robotic missions.

Key Skills
- *Interpreting* images and data
- *Comparing, Sorting,* and *Categorizing* data
- *Generalizing* and *Inferring* from observations
- *Drawing* conclusions and *Speculating*
- *Summarizing* information, *Synthesizing* understanding, and *Presenting* it clearly
- *Supporting* positions with evidence and *Debating* contrasting positions
- *Contributing* thoughtfully to group and class discussions

Materials
- Information Sheets on the planets and moons in the solar system
- Optional -- Supplemental astronomy materials such as texts and CD-ROMs

Preparation
- Collect supplemental astronomy materials
- Provide one set of Planetary Information Sheets for every student, if possible

Which Planetary Bodies in Our Solar System Are Candidates For Life?

Procedure

Day 1: Introduction, preassessment, compare habitability on Earth and Mercury

1. To get a sense of students' prior understanding and to have students take a position and become aware of their preconceptions, ask students, "What makes a planet/moon a good home for living things?" Have them hand in their answers.

   Teacher Note: *When students hand things into a teacher, they often express themselves more completely and clearly than when they just write for themselves. In addition, their responses give the teacher a good idea of students' preconceptions and range of understanding. At the end of the investigation, the teacher will return these responses, and the students will compare their ideas at the beginning and end of the investigation.*

2. To make sure they understand which factors are key in terms of life, conduct a class discussion to develop a set of criteria for habitability and to consider the kinds of life that might live in the conditions found in the solar system. You might ask:
   (a) In general terms what does life need? (*e.g., food, water, habitats, and conducive temperatures*)
   (b) What kinds of things might limit life? (*e.g., extreme temperatures, high levels of radiation such as UV, lack of food and water*)
   (c) Which type(s) of life are best able to survive dryness, low nutrient availability, UV radiation, extreme temperatures, etc.? (*e.g., plant? animal? microbe? large/small organisms?*)

3. To increase student awareness of what life needs and how planetary factors might impact life, have student groups examine Earth's and Mercury's Information Sheets and list as many things as possible that they think make Earth hospitable to life and Mercury seemingly inhospitable to life.

   Teacher Note: *Encourage students to identify specific factors important in supporting life and then compare these factors on both Earth and Mercury. For example:*

Factor Important to Life	Situation on Earth	Situation on Mercury
Temperature	The temperature range enables water to be liquid in nearly every part of Earth.	The side facing the sun is so hot that the chemicals in a cell would be destroyed. The dark side is so cold that chemicals in a cell couldn't react fast enough to support life.
Water	Liquid water circulates nutrients through the environment and prevents the toxic build-up of wastes by removing them.	There is no surface water. Mercury is so hot that any ground water would be very far below the surface.
Protection from Radiation	Our atmosphere shields us from harmful ultra-violet radiation from the sun.	Since there is no atmosphere, life would have to live underground to protect itself.
Atmosphere	Oxygen makes it possible to tap carbon-based energy sources (e.g., sugar, starch, & carbohydrates). Also, many organisms use the carbon dioxide as a carbon source.	There is virtually no atmosphere, so any organisms would be anaerobic and would extract their carbon from minerals containing carbon.
Energy Source	Plants capture sunlight and make possible the food chain. Some microbes can live off the chemical energy in inorganic compounds such as iron.	It's so hot that any life would have to be underground. Light can't penetrate the ground very deeply, so life would have to depend on chemical energy.
Nutrients	Everything we need to build our bodies is already on Earth.	In general, Mercury and Earth have the same chemical composition.

Day 2: Identify Factors Essential For Life, Compare Habitability On Venus And Jupiter

1. To help students differentiate between essential and non-essential factors important to life, have each group present one of the factors they thought made Earth hospitable and Mercury inhospitable and explain their thinking behind their choice. As a class, discuss the merits of each idea and decide how useful a criteria it is for judging the chances for life on one of our solar system's other planets or moons.

   Teacher Note: *Students should come away from this discussion with a clearer (it does not have to be perfect!) sense of what makes a planet conducive for life. What they need before going on is a rudimentary set of criteria for judging the possibility of life on a planet. These criteria will be refined in subsequent activities. For an overview to habitability, see the chart that accompanies this activity entitled "A Table of Key Factors Related to the Habitability of Planets and Moons."*

2. To see if their criteria can help them identify strong candidates for life, have groups examine Venus's and Jupiter's Information Sheets and assess the chances for life on these planets.

   Teacher Note: *Chances for life on both planets are considered almost nil. Venus is so hot that its surface is thought to have melted and remelted several times. If life had existed early in Venus' history, before a runaway Greenhouse Effect raised planetary temperatures to near the melting point of rock, the evidence would have been eradicated when the surface melted in fairly recent times (geologically speaking). Jupiter is made of gas. Gas is too diffuse to concentrate nutrients in a way that life requires. In fact, developing life in the first place requires bringing together compounds essential to life and keeping them together long enough so biotic molecules can form. Life on Earth is thought to have evolved in pools where nutrients could accumulate and become concentrated when water evaporated. In this regard, it is hard to imagine a similar sustained process leading to life on any gaseous planet. Other factors such as low temperatures, the release of large amounts of energy, and pressures thousands times that of Earth make Jupiter a highly unlikely candidate for life.*

3. To strengthen students' abilities to judge the possibilities for life on Venus and Jupiter, repeat the process outlined above in Step 1. As a class, discuss the merits of each idea and decide how useful a criteria it is for judging the chances for life on one of our solar system's other planets or moons.

   Teacher Note: *Students should come away from this discussion with a clearer sense of what makes a planet conducive for life. In this case, they should see that gaseous planets can essentially be eliminated as contenders. They should also refine their previous set of criteria for judging the possibility of life on a planet.*

Day 3: Students Examine the Remaining Planetary Information Sheets

1. To investigate the possibility of life in our solar system, have groups examine the rest of the Planetary Information Sheets and rank each planet as a likely, unlikely, or possible candidate for life. Groups should articulate their reasoning for their choices.

   Teacher Note: *This step is really a puzzle to solve – the Information Sheets contain a lot of information, some more germane to the question of life on other planets and some less. The students' job is to sort through the sheets and find the information that will help them identify the strongest candidates for life. Tell groups that their job is to rank each planet as a likely, unlikely, or possible candidate for life. Remind them that the criteria the class developed over the past two days should help them focus on the key parameters and evaluate each planet and moon. If you feel the students may be overwhelmed by the amount of information, start with the Planetary Information Sheets and introduce the Moon Information Sheets if and when you feel it is appropriate. The moons Europa and Titan have many characteristics deemed important for life, so having students consider moons as potential candidates will most likely increase their number of strong candidates. Sorting information and understanding its significance is an important skill, especially if students are expected to construct meaningful arguments. Provide students enough time to truly consider the available information.*

Day 4: Students Identify The Strongest Candidates For Life And Present Their Choice(S)

1. While the solar system offers quite a range of environments, each planet/moon currently has major limitations for life, as we know it (with the exception of Earth). Have every group prepare a poster report by ranking each planet/moon as either a strong, medium, or weak candidate for life. They should describe their reasoning, articulate what more they would like to know, and summarize their thinking in a table similar to the one below.

Planet/Moon Name	Life is Likely	Maybe (has some things but not all)	Life is Unlikely	Reasoning	Questions
Planet A	X				
Planet B			X		

2. Have each group present its determinations and debate contrasting points of view.

   Teacher Note: *You might want to keep a running tally of the positions developed in the class. Using a format similar to the one above, record each group's analyses on a class chart.*

3. To connect students' conceptions of life in the solar system with their examination of the realities of the solar system, have students answer the following questions:
   (a) What would you expect to see on a planet's or moon's surface if one of the factors that you feel are necessary for life existed there? Did you see any of these things?
   (b) Did you see any life or evidence for life (e.g., forests, cities, canals, roads, grasslands)?
   (c) Based on your examination of the solar system, what are the implications for what the size of organisms might be or where on a planet/moon one might find life?

   Teacher Note: *Depending on whether you want an assessment of student thinking or just have them discuss their work to this point, you can ask students to answer the questions individually or in groups.*

Extension: If students are interested in learning about current explorations of the solar system, have them visit some of the following Web sites that describe past, on-going and future missions:

- NASA's Jet Propulsion Laboratory: http://www.jpl.nasa.gov/
- NASA's Atmospheric Experiment Branch: http://webserver.gsfc.nasa.gov/nojava/missions.html
- NASA's National Space Science Data Center: http://nssdc.gsfc.nasa.gov/planetary/planetary_home.html
- Hawaii Astronomical Society: http://www.hawastsoc.org/solar/eng/homepage.htm

Questions to Follow Up the Investigation

These questions can be used in several ways such as homework, group work, or as assessments.

1. How would you contrast the planets that are likely candidates for life and those that are only moderate possibilities for life? Unlikely candidates for life?
2. What indicators tell us that there is/was life on a planet/moon?
3. As we look for life in our solar system, what should we be looking for?
4. Should we only consider current conditions when thinking about the possibility of life in our solar system?
5. What does the term "alien" mean in our solar system?
6. What does the term alien mean beyond our solar system (i.e., in the galaxy and universe)?
7. How does your current idea of alien life compare with your idea of alien life when you began the investigation?
8. Why might finding actual organisms (alive or fossilized) in the solar system be difficult?
9. How is the search for single-cell life is different than the search for larger life forms?
10. If you were designing a mission to look for evidence of past or present life in the solar system, how would you structure your search?

Questions for Pilot Test Teachers to Consider

(a) What does the word alien mean to students? Do students ever consider an alien's home planet when they discuss aliens? What did they expect to see on the planet surfaces?

(b) What was the students' experience with the Information Sheets? (i.e., amount of information, presentation of information, age-appropriateness of the information)

(c) Did the Information Sheets provide sufficient information to differentiate one planet from another and to have any of them seem like possible candidates for life?

(d) How much time is really required for students to become familiar with the information on the Information Sheets and to identify the elements that make a planet habitable?

(e) How well were students able to identify the salient parameters that might affect life?

(f) How well did students articulate that different types of organisms have different needs?

(g) How did students' notions or the solar system change? Of aliens in our solar system?

(h) How did you wrap up this segment?

(i) What kinds of questions came up in discussions?

(j) Were your students interested in continuing any part of this investigation?

(k) What kind(s) of background information or previous science experience would help students be more successful with this activity?

(l) How would you change this investigation to work better with your students?

A Table of Key Factors Related to the Habitability of Planets and Moons

There are certain preconditions a planet or moon must meet in order to be habitable, and several are listed in the *Factor* column below. The middle column explains why each factor is necessary for life, and the last column describes a variety of ways to achieve these conditions. Because there is more than one way to meet these conditions, one can imagine life arising and/or persisting on quite a variety of planets/moons. This sheet can help you think about each planet or moon in our solar system and assess how strong a candidate it is for having life, either past or present.

Factor	Why It's Important for Life	Ways of Achieving It
Conducive Temperature Range	· Maintains biologically-active molecules such as proteins (too much heat can destroy molecules) · Enables chemicals to react efficiently (reaction rates slow down in colder temperatures. At some point they get so slow that they cannot proceed quickly enough to support processes needed for living. When temperatures are too hot, molecules break apart.)	· If the planet is cold, tap an internal heat source · Orbit an external heat source at the right distance (e.g., Earth) · Avoid wild temperature swings by moderating heat loss such as with an atmosphere · Avoid runaway greenhouse effect by orbiting a star that gives off low to moderate amounts of infrared energy which won't overheat a planet (Earth is an example of this) · Have temperature sensitive processes that help regulate planetary temperatures (e.g., Earth's carbonate-silicate cycle)
Energy Source	· Drives an organism's metabolism and cellular processes	· Using a planetary-based energy source (e.g., chemical energy) · Using an energy source external to the planet (e.g., light energy)
Liquid Water	· Makes nutrients available through weathering · Circulates nutrients through the environment · Prevents toxic build-up of wastes by removing them	· Surface water · Sub-surface water · Water beneath ice caps
Nutrients	· Provide the building blocks for biotic molecules such as proteins and carbohydrates	· Planets/moons have the necessary chemicals in the right form · Recycling processes turn chemicals into biologically-usable forms · Consumers are dependant on producers
Shielding	· Protects organisms from damaging ultra violet radiation	· Liquid water shields organisms below one to two meters · Ice blocks UV radiation · Gaseous atmosphere, and especially ozone, absorbs UV radiation · Solid surface layers block UV radiation completely
Time	· Enables life to arise and diversify · Long-term environmental stability enables increasingly complex organisms to evolve · Catastrophic events (e.g., collisions with large meteors) shorten the time for life to become established or for organisms to evolve. Once life is established, additional major catastrophic events will favor simpler organisms by making life for specialized or complex organisms more difficult.	· Limit the number of catastrophic events. One way to do this is to be in a system with several large planets such as Jupiter that attract much of the inter-planetary debris such as asteroids drifting about. · Orbit a stable, long-lived star such as our sun · Move to a new planet such as when microbes travel on meteorites that have been blasted from a planet's surface or humans using rockets to travel to another planet.

Nat'l Science Standards Addressed in Candidates Activity

Unifying Concepts and Processes	
√	Systems, Order, and Organization
√	Evidence, Models, and Explanation
√	Constancy, Change, and Measurement
√	Evolution and Equilibrium
√	Form and Function
Science as Inquiry	
	Abilities Necessary to do Scientific Inquiry
√	Understandings about Scientific Inquiry
Physical Science	
	Structure of atoms
	Structure and Properties of Matter
√	Chemical Reactions
	Motions and Forces
	Conservation of Energy and Increase in Disorder
√	Interactions of Energy and Matter
Life Science	
√	The cell
	Molecular Basis for Heredity
	Biological Evolution
√	Interdependence of Organisms
√	Matter, Energy, and Organization in Living Systems
	Behavior of Organisms
Earth and Space Science	
√	Energy in the Earth System
√	Geochemical Cycles
√	Origin and Evolution of the Planets
√	Origin and Evolution of Planetary Systems
	Origin and Evolution of the Universe
Science and Technology	
	Abilities of Technological Design
√	Understandings about Science and Technology
Science in Personal and Social Perspectives	
	Personal and Community Health
	Population Growth
	Natural Resources
	Environmental Quality
√	Natural and Human Induced Hazards
	Science & Technology in Local, National, & Global Challenges
History and Nature of Science	
	Science as a Human Endeavor
√	Nature of Scientific Knowledge
	Historical Perspectives